

Claims

1. A soft decision method for demodulating a received signal of a square Quadrature Amplitude Modulation (QAM) consisted of an in-phase signal component and a quadrature phase signal component, wherein a conditional probability vector value being each soft decision value corresponding to a bit position of a hard decision is obtained using a function including a conditional determination operation from the quadrature phase component and the in-phase component of the received signal.
2. The method according to claim 1, wherein the conditional probability vector decision method for a first half of total bits is the same as the decision method for the remaining half of bits, which is determined by substituting the quadrature phase component value and the in-phase component value each other.
3. The method according to claim 2, wherein the conditional probability vector values corresponding to a first to n^{th} bit are demodulated by one of the received signal α and β , and the conditional probability vector values corresponding to the $(n+1)^{\text{th}}$ to $2n^{\text{th}}$ bits of the second half are demodulated by the remaining received signal, and equation applied for the two demodulations has the same method in the first half and the second half.
4. The method according to claim 2, wherein the demodulation method of the conditional probability vector corresponding to an odd-ordered bit is the same as a calculation method of the conditional probability vector corresponding to the next even-ordered bit, where the received signal value used to calculate the conditional probability vector corresponding to the odd-ordered bit uses one of the α and β according to a given combination constellation

diagram and the received signal value for the even-ordered bit uses the

5. The method according to claim 3, wherein the first conditional probability vector is determined by selecting one of the received values α with β according to the combination constellation diagram and applying a following mathematical expression 22, where in the mathematical expression 22,

① an output value is unconditionally determined as $\frac{\alpha}{2^n} \Omega$ [here, Ω is a selected and received value which is one of α and β , and α is an arbitrary real number set according to a desired output scope].

6. The method according to claim 3, wherein the second conditional probability vector is determined by the received value selected when determining the first conditional probability vector and a following mathematical expression 23,

where, in the mathematical expression 23,

① the output value is unconditionally determined as $a(c - \frac{c}{2^{n-1}} |\Omega|)$ [here, Ω is a selected and received value, n is a magnitude of the QAM, that is, a parameter used to determine 2^{2n} , a is an arbitrary real number set according to a desired output scope, and c is an arbitrary constant].

7. The method according to claim 3, wherein the third to n^{th} conditional probability vectors are determined by a received value set when determining the first conditional probability vector and a following mathematical 24,

where in the mathematical expression 24,

first, dividing an output diagram in a shape of a basic probability vector corresponding to each bit is divided into $(2^{k-3} + 1)$ areas,

the basic expression according to the basic form is determined as $a(\frac{d}{2^{n-k+1}} |\Omega| - d)$

③ the output is determined by finding an involved area using the given Ω and substituting a value of $(|\Omega| - m)$ that a middle value is subtracted from each area into the basic expression as a new Ω ,

④ rendering the middle value as $m=2^n$ and substituting the value of $(|\Omega| - m)$ into the basic expression as a new Ω in an area that is in the most outer left and right sides among the divided areas, that is, $(2^{k-2} - 1)2^{n-k+2} < |\Omega|$, [here, Ω is a selected and received value, n is a magnitude of the QAM, that is, a parameter used to determine 2^{2n} , k is conditional probability vector number ($k=3,4,\dots,n$), d is a constant that changes according to the value of k , and a is a constant determining the output scope].

8. The method according to claim 3, wherein the $(n+1)^{th}$ to $2n^{th}$ conditional probability vectors are sequentially obtained using the received value that is not selected when the first conditional probability vector is determined and the mathematical expressions described above (however, the number k of the conditional probability vector included in the mathematical expression 24 sequentially substitutes 3 to n with $n+1$ to $2n$).

9. The method according to claim 4, the first conditional probability vector is determined by selecting any one of the received values α and β according to a form of the combination constellation diagram and then according to a mathematical expression 25, where in the mathematical expression 25,

③ the output value is unconditionally determined as $-\frac{a}{2^n} \Omega$ [here, Ω is a selected and received value that is one of α and β , n is a magnitude of the QAM, that is, a parameter used to determine 2^{2n} , and a is an arbitrary real number set according to a desired output scope].

10. The method according to claim 4, wherein the second conditional probability vector performs a calculation by substituting the received value selected with the received value that is not selected in the method for obtaining the first conditional probability vector of the second form.

11. The method according to claim 4, wherein the third conditional probability vector selects one of the received values α and β according to a form of the combination constellation diagram, uses a following mathematical expression 26 in the case of $\alpha \beta \geq 0$, and determines by substituting the received value selected in the mathematical expression 26 with the received value that is not selected in the expression in the case of $\alpha \beta < 0$, where in the mathematical expression 26, the output value is determined as $a(c - \frac{c}{2^{n-1}} |\Omega|)$ [here, Ω is a selected and received value, n is a magnitude of the QAM, that is, a parameter used to determine 2^{2n} , a is an arbitrary real number set according to a desired output scope, and c is an arbitrary constant].

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12. The method according to claim 4, wherein the fourth conditional probability vector is calculated by substituting each of received values used with each of the received values that are not used in the method for obtaining the third conditional probability vector of the second

form in the cases of $\alpha \beta \geq 0$ and $\alpha \beta < 0$.

13. The method according to claim 4, wherein the fifth conditional probability vector selects one of the received values α and β according to the form of the combination constellation diagram, uses a following mathematical expression 27 in the case of $\alpha \beta \geq 0$, and determines by substituting the received value selected in the mathematical expression 27 with the received value that is not selected in the expression in the case of $\alpha \beta < 0$, where in the mathematical expression 27,

① first, dividing an output diagram in a shape of a basic V form, the conditional probability vector corresponding to each bit is divided into 2 areas,

② the basic expression according to the basic form is determined as $a(\frac{d}{2^{n-2}}|\Omega|-d)$,

③ the output is determined by finding an involved area using the given Ω and substituting a value of $(|\Omega|-m)$ that a middle value is subtracted from each area into the basic expression as a new Ω ,

④ rendering the middle value as $m=2^n$ and substituting the value of $|\Omega|-m$ into the basic expression as a new Ω in an area that is in the most outer left and right sides among the divided areas, that is, $7 \cdot 2^{n-3} < |\Omega|$, [here, Ω is a selected and received value, n is a magnitude of the QAM, that is, a parameter used to determine 2^{2n} , d is a constant, and a is a constant determining the output scope].

14. The method according to claim 4, wherein when the magnitude of QAM is 64-QAM, the sixth conditional probability vector is calculated by substituting each of received values used with each of the received values that are not used in the method for obtaining the fifth conditional probability vector of the second form in the cases of $\alpha \beta \geq 0$ and $\alpha \beta < 0$.

15. The method according to claim 4, wherein when the magnitude of QAM is more than 256-QAM, the fifth to $(n+2)^{\text{th}}$ conditional probability vector select one of the received values α and β according to the form of the combination constellation diagram, is determined by a following mathematical expression 28 in the case of $\alpha \beta \geq 0$, and determines by substituting the received value selected in the mathematical expression 28 with the received value that is not selected in the expression in the case of $\alpha \beta < 0$, where in the mathematical expression 28,

① first, dividing an output diagram in a shape of a basic V form, the conditional probability vector corresponding to each bit is divided into $(2^{k-5}+1)$ areas,

② the basic expression according to the basic form is determined as $a(\frac{d}{2^{n-k+3}} |\Omega| - d)$,

③ the output is determined by finding an involved area using the given Ω and

substituting a value of $|\Omega| - m$ that a middle value m (for example, in the case of $k=6$, since repeated area is 1, this area is $2^{n-2} \leq |\Omega| < 3 \cdot 2^{n-2}$ and the middle value is $m=2^{n-1}$) is subtracted from each area into the basic expression as a new Ω ,

④ rendering the middle value as $m=2^n$ and substituting the value of $|\Omega| - m$ into the basic expression as a new Ω in an area that is in the most outer left and right sides among the divided areas, that is, $(2^{k-2} - 1)2^{n-k+2} < |\Omega|$, [here, k is the conditional probability vector number (5, 6, ..., n), Ω is a selected and received value, n is a magnitude of the QAM, that is, a parameter used to determine 2^{2n} , a is a constant determining the output scope, and d is a constant that changes according to a value of k].

16. The method according to claim 4, wherein when the magnitude of QAM is more than 256-QAM, the $(n+3)^{\text{th}}$ to $(2n)^{\text{th}}$ conditional probability vectors is selected by the

mathematical expression 28 using the received value that is not selected

fifth to $(n+2)^{\text{th}}$ conditional probability vector of the second form in the case of $\alpha \beta \geq 0$,

and is obtained by substituting the received value selected in the mathematical expression 28 with the received value that is not selected in the expression in the case of $\alpha \beta < 0$.

17. The method according to claim 3, wherein the first conditional probability Vector of the first form is determined by selecting any one of the received values α and β according to a form of the combination constellation diagram and then according to a mathematical expression 29, where in the mathematical expression 29,

① if $|\Omega| \geq 2^n - 1$, the output is determined as $a * \text{sign}(\Omega)$,

also, ② $|\Omega| \leq 1$, the output is determined as $a * 0.9375 * \text{sign}(\Omega)$,

also, ③ $1 < |\Omega| \leq 2^n - 1$, the output is determined as $a * \text{sign}(\Omega) \left[\frac{0.0625}{2^n - 2} (|\Omega| - 1) + 0.9375 \right]$,

[here, Ω is anyone of the received values α and β , 'sign(Ω)' indicates the sign of the selected and received value, 'a' is an arbitrary real number set according to a desired output scope, α is a received value of I (real number) channel, and β is a received value of Q(imaginary number) channel].

18. The method according to claim 3, wherein the second conditional probability vector of the first form is determined by the received value selected when determining the first conditional probability vector and the mathematical expression 30, where in the mathematical expression 30

① if $2^n - 2^{n(2-m)} \leq |\Omega| \leq 2^n - 2^{n(2-m)} + 1$, the output is determined as $a * (-1)^{m+1}$,

② if $2^{n-1} - 1 \leq |\Omega| \leq 2^{n-1} + 1$, the output is determined as $a * 0.9375(2^{n-1} - |\Omega|)$,

③ if $2^{n-1}-2^{(n-1)(2-m)}+m \leq |\Omega| \leq 2^n-2^{(n-1)(2-m)}+m-2$,

the output is determined as $-a * \left[\frac{0.0625}{2^{n-2}} (|\Omega|-2m+1) + 0.9735(-1)^{m+1} + 0.0625 \right]$,

[here, Ω is a selected and received value, n is the magnitude of QAM, that is, a parameter used to determine 2^{2n} , 'a' is an arbitrary real number set according to a desired output scope, and $m=1,2$].

19. The method according to claim 3, wherein the third to $(n-1)^{th}$ conditional probability vectors of the first form are determined by the received value selected when determining the first conditional probability vector and the mathematical expression 31, where in the mathematical expression 30,

① if $m*2^{n-k+2}-1 < |\Omega| \leq m*2^{n-k+2}+1$, the output is determined as $a*(-1)^{m+1}$,

also, ② if $(2\ell-1)*2^{n-k+1}-1 < |\Omega| \leq (2\ell-1)*2^{n-k+1}+1$,

the output is determined as $a*(-1)^{\ell+1}0.9375\{(|\Omega|-(2\ell-1)*2^{n-k+1})$,

also, ③ if $(P-1)*2^{n-k+1}+1 < |\Omega| \leq P*2^{n-k+1}-1$,

when P is an odd number, the output is determined as

$$a * \left[\frac{0.0625}{2^{n-k+1}-2} [(-1)^{(p+1)/2+1} * |\Omega| + (-1)^{(p+1)/2} [(P-1)*2^{n-k+1}+1] + (-1)^{(p+1)/2}] \right],$$

when P is an even number, the output is determined as

$$a * \left[\frac{0.0625}{2^{n-k+1}-2} [(-1)^{p/2+1} * |\Omega| + (-1)^{p/2} (P*2^{n-k+1}-1)] + (-1)^{p/2+1} \right],$$

[here, Ω is a selected and received value, $m=0, 1, \dots, 2^{k-2}$, and ℓ is $1, 2, \dots, 2^{k-2}$, k is

conditional probability vector number ($k=3, \dots, n-1$)].

20. The method according to claim 3, wherein the n^{th} conditional probability Vector of

the first form is determined by the received value selected w conditional probability vector and the mathematical expression 32, where in the mathematical expression 32,

① if $m \cdot 2^2 - 1 \leq |\Omega| \leq m \cdot 2^{n_2} + 1$, the output is determined as $a \cdot (-1)^{m+1}$,

also, ② if $(2\ell - 1) \cdot 2^1 - 1 < |\Omega| \leq (2\ell - 1) \cdot 2^1 + 1$,

the output is determined as $a \cdot (-1)^{\ell + 1} \cdot 0.9375 \{(|\Omega| - (2\ell - 1) \cdot 2^1)\}$,

[here, Ω is a selected and received value, $m=0, 1, \dots, 2^{n-2}$, and $\ell = 1, 2, \dots, 3^{n-2}$].

21. The method according to claim 3, wherein the $(n+1)^{\text{th}}$ to $2n^{\text{th}}$ conditional probability vectors of the first form are sequentially obtained using the received value that is not selected when determining the first conditional probability vector and the mathematical expressions 30 to 32, respectively [however, the conditional probability vector number k included in the mathematical expression 31 is sequentially used as 3 to $n-1$ instead of $n+3$ to $2n-1$].

22. The method according to claim 4, wherein the first conditional probability Vector of the second form is determined by selecting any one of the received values α and β according to a form of the combination constellation diagram and then according to a mathematical expression 33, where in the mathematical expression 33,

① if $|\Omega| \geq 2^n - 1$, the output is determined as $-a \cdot \text{sign}(\Omega)$,

also, ② $|\Omega| \leq 1$, the output is determined as $a \cdot 0.9375 \cdot \text{sign}(\Omega)$,

also, ③ $1 < |\Omega| \leq 2^n - 1$, the output is determined as

$$-a \cdot [\text{sign}(\Omega) \frac{0.0625}{2^n - 2} (|\Omega| - 1) + 0.9275]$$

[here, Ω is the selected and received value, 'sign(Ω)' indicates the sign of the selected and received value, a is an arbitrary real number set according to a desired output scope, α is a

received value of I (real number) channel, and β is a received value of Q (imaginary number) channel].

23. The method according to claim 4, wherein the second conditional probability vector of the second form is calculated by substituting the received value selected in the method for obtaining the first conditional probability vector of the second form with the received value that is not selected in the method.

24. The method according to claim 4, wherein the third conditional probability vector of the second form selects anyone of the received values α and β according to the combination constellation diagram, and determines using the following mathematical expression 34 in the case of $\alpha * \beta \geq 0$, and substituting the selected and received value in the mathematical expression 34 with the received value that is not selected in the mathematical expression 34 in the case of $\alpha * \beta < 0$, where in the mathematical expression 34,

① if $2^n - 2^{n(2-m)} \leq |\Omega| \leq 2^n - 2^{n(2-m)} + 1$, the output is determined as $a * (-1)^m$,

also, ② if $2^{n-1} - 1 \leq |\Omega| \leq 2^{n-1} + 1$, the output is determined as $a * 0.9375(|\Omega| - 2^{n-1})$,

also, ③ if $2^{n-1} - 2^{(n-1)(2-m)} + m \leq |\Omega| \leq 2^n - 2^{(n-1)(2-m)} + m - 2$,

the output is determined as
$$a * \left[\frac{0.0625}{2^n - 2} (|\Omega| - 2m + 1) + 0.9735(-1)^m - 0.0625 \right]$$
,

[here, Ω is a selected and received value, 'a' is an arbitrary real number set according to a desired output scope, α is a received value of I (real number) channel, β is a received value of Q (imaginary number), and $m=1,2$].

25. The method according to claim 4, wherein when the magnitude of QAM of the second form is less than 64-QAM, the fourth conditional probability vector is calculated by

substituting each of received values used with each of the received
the method for obtaining the third conditional probability vector of the second form in the cases
of $\alpha * \beta \geq 0$ and $\alpha * \beta < 0$.

26. The method according to claim 4, wherein when the magnitude of QAM of the
second form is 64-QAM, the fifth conditional probability vector select one of the received
values α and β according to the form of the combination constellation diagram, and
determines using the following mathematical expression 35 in the case of $\alpha * \beta \geq 0$, and
substituting the received value selected in the mathematical expression 35 with the received
value that is not selected in the expression in the case of $\alpha * \beta < 0$, where in the mathematical
expression 35,

① if $m*2^{n-1}-1 \leq |\Omega| \leq m*2^{n-1}+1$, the output is determined as $a*(-1)^{m+1}$,

also, ② if $(2\ell-1)*2^{n-1}-1 < |\Omega| \leq (2\ell-1)*2^{n-1}+1$,

the output is determined as $a*(-1)^{\ell+1}\{0.9375|\beta|-0.9375(2\ell-1)*2^{n-1}\}$,

[here, Ω is a selected and received value, 'a' is an arbitrary real number set according
to a desired output scope, α is a received value of I (real number) channel, β is a received
value of Q(imaginary number) channel, $m=0, 1, 2$, and $\ell=1, 2$].

27. The method according to claim 4, wherein when the magnitude of QAM of the
second form is 64-QAM, the sixth conditional probability vector is calculated by substituting
each of received values used with each of the received values that are not used in the method
for obtaining the fifth conditional probability vector of the second form in the cases of
 $\alpha * \beta \geq 0$ and $\alpha * \beta < 0$.

28. The method according to claim 4, wherein when the magnitude of QAM of the

second form is more than 256-QAM, the fourth to n^{th} conditional probability vectors of the received values α and β according to the form of the combination constellation diagram, is determined by a following mathematical expression 36 in the case of $\alpha * \beta \geq 0$, and determines by substituting the received value selected in the mathematical expression 36 with the received value that is not selected in the expression in the case of $\alpha * \beta < 0$, where in the mathematical expression 36, where in the mathematical expression 36,

① if $m * 2^{n-k+3} - 1 < |\Omega| \leq m * 2^{n-k+3} + 1$, the output is determined as $a * (-1)^{m+1}$,

also, ② if $(2\ell - 1) * 2^{n-k+2} - 1 < |\Omega| \leq (2\ell - 1) * 2^{n-k+2} + 1$,

the output is determined as $a * (-1)^{\ell+1} \{0.9375(|\Omega| - 0.9375(2\ell - 1) * 2^{n-k+2})\}$,

also, ③ if $(P-1) * 2^{n-k+2} + 1 < |\Omega| \leq P * 2^{n-k+2} - 1$,

when P is an odd number, the output is determined as

$$a * \left[\frac{0.0625}{2^{n-k+2}-2} [(-1)^{(p+1)/2+1} * |\Omega| + (-1)^{(p+1)/2} [(P-1) * 2^{n-k+2} + 1]] + (-1)^{(p+1)/2} \right],$$

when P is an even number, the output is determined as

$$a * \left[\frac{0.0625}{2^{n-k+1}-2} [(-1)^{p/2+1} * |\Omega| + (-1)^{p/2} (P * 2^{n-k+2} - 1)] + (-1)^{p/2+1} \right],$$

[here, k is conditional probability vector numbers (4, 5, ..., n), Ω is a selected and received value, 'a' is an arbitrary real number set according to a desired output scope, α is a received value of I (real number) channel, β is a received value of Q (imaginary number) channel, $m = 0, 1, \dots, 2^{k-3}$, ℓ is $1, 2, \dots, 2^{k-3}$, and $p = 1, 2, \dots, 2^{k-2}$].

29. The method according to claim 4, wherein when the magnitude of QAM of the second form is more than 256-QAM, the $(n+1)^{\text{th}}$ conditional probability vectors is a received value selected when determining the fourth to n^{th} conditional probability vector of the second form, is determined using the mathematical expression 37 in the case of $\alpha * \beta \geq 0$, and is

obtained by substituting the received value selected in the mathematical expression 37, received value that is not selected in the expression in the case of $\alpha * \beta < 0$, where in the mathematical expression 37,

Ⓐ if $m*2^2-1 \leq |\Omega| \leq m*2^2+1$, the output is determined as $a*(-1)^{m+1}$,

also, Ⓑ if $(2\ell-1)*2^1-1 < |\Omega| \leq (2\ell-1)*2^1+1$,

the output is determined as $a*(-1)^{\ell+1}\{0.9375(|\Omega|-0.9375(2\ell-1)*2^1)\}$,

[here, Ω is a selected and received value, 'a' is an arbitrary real number set according to a desired output scope, α is a received value of I (real number) channel, β is a received value of Q (imaginary number) channel, $m=0, 1, \dots, 2^{k-2}$, and ℓ is $1, 2, \dots, 3^{k-2}$].

30. The method according to claim 4, wherein when the magnitude of QAM of the second form is more than 256-QAM, the method for obtaining the $(n+2)^{\text{th}}$ conditional probability vector is the same as the method for obtaining the fourth conditional probability vector in the case that the magnitude of QAM of the second form is less than 256-QAM.

31. The method according to claim 4, wherein when the magnitude of QAM of the second form is more than 256-QAM, the $(n+3)^{\text{th}}$ to $(2n-1)^{\text{th}}$ conditional probability vectors are calculated by substituting each of received values used with each of the received values that are not used when determining the fourth to n^{th} conditional probability vectors in the cases of
) $\alpha * \beta \geq 0$ and $\alpha * \beta < 0$ when the magnitude of QAM of the second form is more than 256-QAM.

32. The method according to claim 4, wherein when the magnitude of QAM of the second form is more than 256-QAM, the $2n^{\text{th}}$ conditional probability vector is calculated by
 5 substituting each of received values used with each of the received values that are not used

when determining the fourth to the $(n+1)^{\text{th}}$ conditional probability
 $\alpha * \beta \geq 0$ and $\alpha * \beta < 0$ when the magnitude of QAM of the second form is more than
256-QAM.

33. An apparatus for demodulating an QAM receiving signal consisted of an in-phase
signal component and an quadrature phase signal component, wherein the apparatus comprises
a conditional probability vector determination unit for obtaining a conditional probability
vector value being each soft decision value corresponding to a bit position of a hard decision is
obtained using a function including a conditional determination operation from the quadrature
phase component and the in-phase component of the received signal.

34. The apparatus according to claim 33, wherein in the conditional probability vector
determination unit, an operation for determining the conditional probability vector for a first
half of total bits is the same as an operation for determining the conditional probability vector
for the remaining half bits, and is determined by substituting the quadrature phase component
value with the in-phase component value, respectively.

35. The apparatus according to claim 33 or 34, wherein in the conditional probability
vector operation unit, the conditional probability vector values corresponding to the first to n^{th}
bits are demodulated by anyone of the received signals α and β , and the conditional
probability vector values corresponding to the $(n+1)^{\text{th}}$ to the $2n^{\text{th}}$ bits of the second half are
demodulated by the received signal of the remaining one, and first half and second half
equations applied to the two demodulations are same.

36. The apparatus according to claim 33 or 34, wherein in the conditional probability

vector operation unit, the demodulation operation of the con
corresponding to an odd-ordered bit is identical to the operation of the conditional probability
vector corresponding to the next even-ordered bit, and the received signal value to calculate the
conditional probability vector corresponding to the odd-ordered bit uses anyone of α and β
according to a given combination constellation diagram, and the received signal value for the
even-ordered bit uses the remaining one.